THE IMPORTANCE OF UPSKILLING OUR UNDERSTANDING OF URBAN TRAVELLER BEHAVIOUR

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ABSTRACT

Upskilling our ability to quantify urban traveller trip preferences and behaviour and incorporating these findings into urban transport policy development at all levels of government is a key requirement for successful transport project conceptualisation, planning, design, implementation, and evaluation. Transport planners and economists in South Africa have historically had limited insight into the trip making behaviour of urban and inter-urban travellers by means of their stated and / or revealed journey preferences. A consequence has been deficient transport project conceptualisation, design and operations planning for both public transport and roads schemes. The resulting adverse financial implications have been substantial and are enduring. Strategic urban transportation demand models that are used to provide scheme demand and revenue forecasts have developed the unenviable reputation of providing estimates that are far in excess of what has actually materialised, in large part due to inadequate mode and route choice behavioural modelling. The economic appraisals for urban transport projects, when undertaken, have not been transparent, and the provenance of key micro-economic measures such as the work and non-work related values of travel time (VTT) are uncertain. Transportation demand models cannot produce reliable demand forecasts without robust estimates of the value of travel time and cater for its heterogeneity with appropriate traveller market segmentation. Mode choice models themselves require careful design and a high degree of insight into trip making behaviour and user preferences and cannot forecast reliable mode shares without this. Using evidence from transport project case studies and recent research initiatives this paper demonstrates the importance and value for money proposition of upskilling our ability to quantify traveller preferences and incorporate these findings into urban transport policy, project design and operations, and transportation demand models.

1. INTRODUCTION

Ortuzar and Willumsen state in their influential transportation modelling textbook, Modelling Transport (2011) that *"The issue of mode choice, therefore, is probably the single most important element in transport planning and policy making."* They continue to state that *"it is thus important to develop and use mode choice models that are sensitive to those attributes of travel that influence individual choices of mode"*. This requirement is not straightforward, as mode choice behaviour is a complex process influenced by several modal operational and fare attributes and personal preferences wrapped up into the definition and formulation of trip utility. This complexity is further influenced by choice heterogeneity, especially in societies where there are high levels of income disparity, mode affordability, car ownership and differing levels of access to public transport modes. Ortuzar and Willumsen (2024) postulate that the probability of individuals choosing a given alternative is a function of their socioeconomic characteristics and the relative attractiveness of the alternative. The attractiveness of an alternative mode is captured by the modal utility. The economic construct of utility is well grounded in economic theory. The premise is that individuals will seek to maximise their utility, and hence will choose the alternative that achieves this. The utility expression is formulated as the weighted sum of defined utility attributes, with the attribute coefficients representing the relative weights. Most commonly a linear-in-coefficients form of expression is used. Importantly, the coefficients in the utility expressions represent marginal rates of substitution. The most important of these coefficient ratios is that of travel time and travel cost - this ratio represents the monetary amount an individual is willing to pay to save a specific amount of travel time. This measure is commonly referred to as the value of travel time (VTT) and is measured in Rands per hour. The VTT is a key micro-economic measure that is used in the valuation of travel time saving benefits in economic appraisals and in transportation demand models to convert trip cost elements (e.g. petrol and tolls) into equivalent time units.

Discrete choice models were formulated to determine the probability of an option choice based on the premise of utility maximisation. These models have application limitations, and the use of the right form of discrete choice model for the system to be modelled is a key consideration. The model form determines the experimental design for traveller mode or route preference data collection (whether stated (SP) and/or revealed preference (RP)), and hence the questionnaire design. The analyst must use inputs from travellers (e.g. with focus groups) as well as their own knowledge and experience to determine the appropriate form of utility expression, the attributes in the utility expression, and the attribute levels to be used in the choice sets of SP surveys.

The same issues are applicable to the simulation of route choice behaviour using discrete choice models based on utility maximisation. Having chosen to use the car mode, the traveller must then choose their preferred route based on several route attributes, the levels of these attributes, and their own trip preferences. The simulation of route choice is arguably more complex than mode choice in urban areas due to the large number of possible alternative routes and the difficulty of determining realistic route attribute levels that reflect actual driving conditions, including the effects of traffic congestion (Wardman & Ibanez, 2012). The potential for route correlation when alternative routes have overlaps, the issue of linked trips (e.g. the need to drop-off children at school en-route to work), and the issues associated with estimating models with non-labelled alternatives (Hayes, 2023) must all be taken into consideration. The inclusion of route attributes such as travel time (including disaggregation into stop-start time, slowed-down time and free-flow time), vehicle running costs, tolls and trip time reliability in the utility expression requires the use of specific types of discrete choice models to simulate the choice of route alternatives, especially if there is route overlap (Cascetta & Nuzollo et al., 1996).

The apparent reluctance by authorities to budget for the collection of traveller choice preference data for mode and route choice modelling compounds the issue. The last stated preference surveys done in Tshwane and Johannesburg were in 2010 and 2014 respectively (City of Tshwane, 2010; City of Johannesburg, 2014). The last Gautrain user choice surveys were done in the early 2000's by the bidders for the current Gautrain concession that ends in March 2026. SANRAL did not undertaken any route choice SP /RP surveys when planning the Gauteng Freeway Improvement Project (GFIP) e-toll scheme between 2008 and 2010. None have been done since despite the Gauteng Province E-Toll Advisory Panel Report (2014) highlighting this as a shortcoming of the GFIP planning process.

So it is not surprising that so many mode and route choice models in South Africa over the last two decades have been inadequate when estimating modal or route demand and the associated fare and toll revenues using traditional four-step transportation demand models. The shortcomings of four-step models have been well documented (Ortuzar & Willumsen, 2024; Mladenovic & Trifunovic, 2014). Some of the demand over-estimation can be put down to optimism bias described by Flyvbjerg (2005). Examples of demand over-estimation include the Gautrain, that was forecast to carry 100,000 passenger trips per weekday by 2016. The actual demand at that time was an average of 57,000 trips per weekday (Gleason, 2013). The Rea Vaya bus rapid transit system was forecast to carry 140,000 trips per day when the patronage of Phase 1b of the system completed ramp up. The actual system ridership in 2017 was 53,000 trips per day (City of Johannesburg, 2017). The MyCiti BRT system in Cape Town has fared somewhat better, with pre-pandemic daily weekday ridership of 70,000 being less than the anticipated 100,000 daily trips (IDTP Africa, 2021). While technical, operational, and administrative issues have negatively impacted rail and BRT patronage, unreliable patronage models have also contributed.

The optimistic Rea Vaya ridership and revenue forecasts contributed to the “unrealistic expectations” of high ridership and low operating subsidies (Harber & Bryer, 2020). In 2017 this resulted in questions being raised about the viability of the South African BRT systems by senior politicians (Venter, 2017). Based on the poor ridership projections experienced in Johannesburg and Cape Town, the other metros rolling out BRT systems, i.e. Durban and Tshwane, should be cautious and ensure they employ state of the art methods to estimate mode share as part of their transportation demand models. Hayes and Venter (2017) and Venter (2016) suggested that the high capital expenditure (CAPEX) and operational expenditure (OPEX) approach for BRT systems in South Africa may be misplaced, as they do not cater for what is important to travellers, i.e. less emphasis on travel time savings and more emphasis on reliable services and lower fares.

In summary, upskilling our ability to quantify urban traveller trip preferences and behaviour and incorporating these findings into urban transport policy and demand models is a key requirement for successful transport project conceptualisation, planning, design, implementation, and evaluation.

2. MODE AND ROUTE CHOICES ARE NOT WHAT WE THINK THEY ARE

Over the last 20 years, the mode choice models deployed in traditional four step transportation models have been multinomial logit models (MNL). This model is suitable for simulating the choice of alternative from a defined set of alternatives based on the alternative utilities. While MNL models are considered the “workhorse” of discrete choice models, they have important, recognised constraints, i.e. the independent and identically distributed (IID) observation assumption and the independence from irrelevant alternatives (IIA) constraint (Hensher, Rose & Greene, 2015; Ortuzar & Willumsen, 2024). The IID assumption assumes that the probabilities of different outcomes for each observation are independent of each other (even from the same survey respondent), and each observation provides independent information about the attribute coefficients of the model. Violations of this constraint will result in the estimation of erroneous attribute coefficients including the wrong signs which invalidate a model. The IIA constraint requires the alternatives in a choice set not to be correlated, i.e. choosing one alternative over another must be unaffected by the presence or absence of other alternatives in the choice set. Violation of the IID/IIA constraints requires the use of an alternative discrete model types such as the nested logit multinomial model (NML). In particular, the IIA constraint is violated when modelling the choice between various access (and egress) modes to a main mode, such as feeder modes to a BRT trunk route (e.g. feeder buses, walk, and taxi) and access modes to a train service (e.g. park and ride, feeder buses, walk and drop-off). The application of NML models can reveal important and interesting insights into commuter behaviour, including the underlying structure of preferences among alternatives and the accommodation of heterogeneous preferences among individuals or segments within the population.

Using NML models, research in 2019 (Watts, 2020) illustrated that Gautrain commuters showed different behavioural characteristics during their access and egress trips, with their VTT for the access trip (R41/hour) being nearly half the value of their egress trip (R80/hour). The reason for this behaviour is uncertain, but most likely attributable to their increased urgency and anxiety to get to work on time during their egress trip. Certainly the trip utility they associate with their access and egress trips could affect their choice of the main (Gautrain) mode. The simulation of the choice between the Rea Vaya access modes (walk, taxi, feeder buses) using NML models (van Zyl et al., 2022), also illustrated the high levels of utility associated with the access modes, with the high likelihood that the utility associated with access modes would also influence the choice of the main Rea Vaya (trunk) mode. The results of this research showed the importance of modelling (at least) the choice of access mode for a main public transport mode, as this could affect the choice of the main mode. It also suggests that planners should consider measures to get passengers to their final destinations more quickly, as this will increase the overall utility of the trip and increase the demand for the main mode.

Research into commuter route choice in dense, congested urban road networks by Hayes (2023) demonstrated that car commuters associated different values of travel time with different levels of congestion. Route choice models using MNL and latent class logit (LCL) models with a sample of high income car commuters highlighted that lower VTTs were associated with higher levels of service (LOS). The VTT for free flow travel was significantly lower than for slowed-down time and stop-start time. The congestion multipliers (i.e. the ratios of free-flow: slowed-down and free flow: stop-start VTT) were 1.23 and 2.24 respectively, showing that motorists associated high levels of disutility (and hence higher levels of VTT) with increasing levels of congestion. These multipliers are similar to those measured internationally (Wardman & Ibanez, 2012). The models also showed that the commuters considered trip time reliability as contributing significantly to their overall trip utility. The LCL model showed 57% of the sample perceived freeway tolls as being a significant part of their overall trip utility, with all three travel time categories (free-flow, slowed-down and stop start travel time) also being statistically significant in the utility expression. Essentially this class requires value for money when they pay a toll. The other 43% did not perceive the toll cost to be a significant component of utility, but perceived stop-start time to be a disproportionally high contributor to trip utility, i.e. they were prepared to pay their way out of high levels of congestion, irrespective of the toll cost.

As part of an assessment to determine the factors that caused the financial failure of several urban toll roads in Australia due to actual vehicle demand that was substantially lower than predicted by transport models, Hensher et al. (2016) identified that commuting motorists in Sydney perceived varying VTTs in cumulative toll conditions. They determined that as the motorist’s toll debt accumulated over time and as the motorist’s budget for transport was depleted, their perception of VTT reduced, i.e. they were willing to pay less in tolls for trip time savings offered by the tolled roads when their toll saturation level was approached. The net result was they either used non-tolled routes or changed mode. It was estimated that approximately one third of the over estimation of traffic demand could be attributed to this reducing VTT trend. No research into this phenomenon has been undertaken in South Africa.

The models and issues described clearly highlight several issues. Firstly, that mode and route choice isn’t what we thought it was. There are more trip attributes contributing significantly to trip utility than what we have accounted for in the past. Secondly, that transport planners, modellers and economists currently still do not have adequate insight into urban commuter behaviour across all modes. The gaps in these insights will continue to cast doubt on the reliability and robustness of demand and revenue forecasts. Thirdly, that at a time when transport authorities require more robust forecasts of demand and revenue to ensure value for money investments and to reduce the financial and economic risks associated with urban transportation schemes, planners need to adopt the use of more complex mode and route choice models to achieve this. And finally, to achieve the first three issues, there needs to be the recognition of the importance of high quality trip preference data, and the necessary investment in ongoing SP and RP data collection.

3. THE VALUE OF TRAVEL TIME (VTT)

A key economic measure that is derived from mode and route choice models is the VTT. VTT is a willingness-to-pay measure that estimates the monetary value that travellers are willing to pay to save a unit amount of travel time and is commonly stated in Rands per hour. This economic measure is of importance to policy makers, transport planners and economists. It is the basis for the planning of urban toll schemes and setting toll tariffs and provides clarity for the development of public transport fare policy.

There are no clear guidelines in South Africa for VTTs that should be used in economic appraisals and transport models, despite suggestions made by SANRAL for such guidelines to be drawn up based on evidence derived from mode and route choice models (South African National Roads Agency Ltd, 2010). The result has been the use of VTTs in economic appraisals with uncertain provenance and, in some cases, the use of historical VTTs that were derived from inadequate SP/RP data collection surveys (Hayes, 2021) (and with these inadequacies built into the MNL models).

Figure 1 shows historical values of VTT for commuters in Gauteng Province derived by various authorities as well as from recent research between 2010 and 2022. All the values have been estimated at 2020 levels. 2020 values of the historical VTT values were estimated by using the annual Gauteng real wage growth with a 50% elasticity value, i.e. annual VTT growth was estimated as 50% of annual real income growth (Small & Verhoef, 2007). Between 2000 and 2020 the average overall real wage increase was 2.3% per annum (Mosomi & Wittenberg, 2020).

Several important conclusions can be drawn from Figure 1. There is no clear trend in the values, with high levels of heterogeneity between modes and income groups. The VTT estimates between 2010 and 2014 are lower than those estimated after that time, possibly due to improved experimental designs and the types of models applied after 2014. It is noticeable that the Soweto BRT access mode value is only slightly lower than the Gautrain commuter access value, which is an interesting result, as there is the expectation that Gautrain user incomes are higher than for BRT users. The Gauteng car commuter values for free-flow time and slowed-down time are similar to the Gautrain and BRT access mode values, but the car commuter value for stop-start time is significantly higher. The stop-start VTT is at the same level as the average Gautrain user combined access and egress value.

This result reflects the high level of disutility associated with the Gautrain access and egress modes insofar as travel time is concerned.

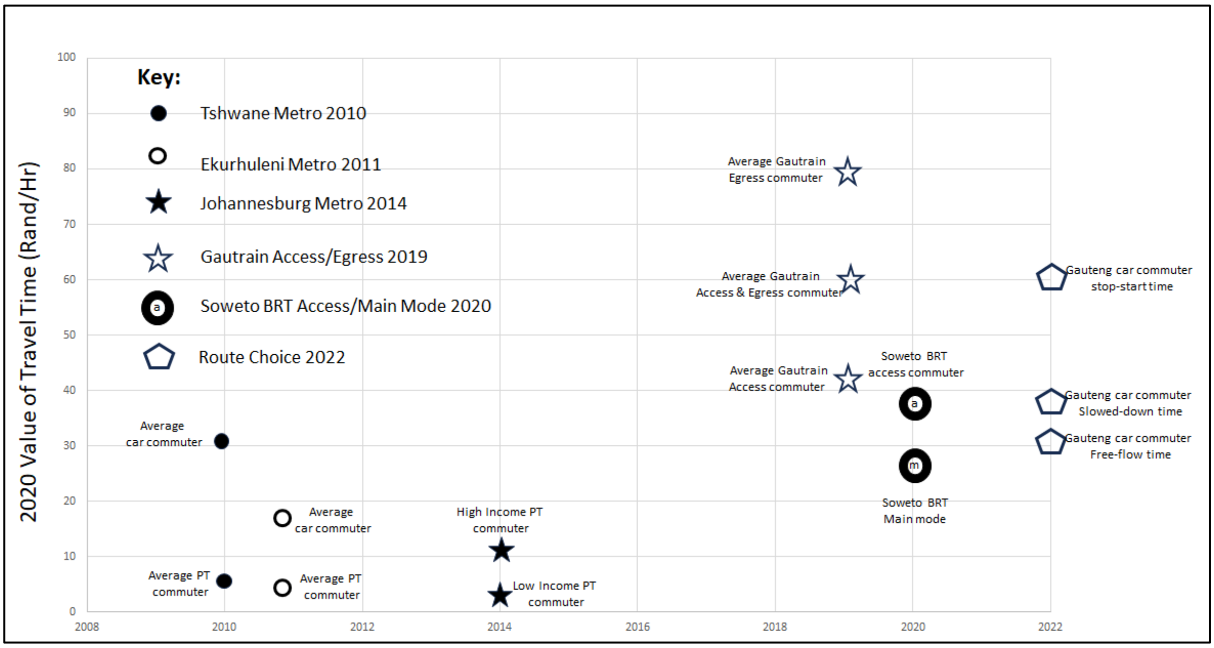

Figure 1: Estimated Values of Commuter Travel Time in Gauteng Province (2010 to 2022)

These VTTs provide a clear indication that the VTTs vary significantly between commuter income groups, modes and levels of road congestion. Models that adopt average VTTs or more aggregate VTT levels will be produce less reliable forecasts of patronage and revenue. The risks of adopting average VTTs in models assumed as being representative of skewed distributions of values are highlighted by Hensher and Goodwin (2004). In these circumstances for toll roads, for example, there will be a tendency to overestimate the toll revenue and underestimate the traffic impact of a charge, because for a given mean VTT, there will be a smaller number of individuals who are actually prepared to pay the toll. Developing choice models to take account of all these variations is however not straightforward. Obtaining more comprehensive insights into commuter behaviour and the VTTs for these segmented markets will require a significant data collection and model estimation effort.

Travel time savings can make up a significant proportion of the overall benefits in economic appraisals. Mackie et. al. (2001) found that in the UK that travel time saving benefits can make up as much as 80% of the overall transport scheme benefits, especially for roads projects. Hayes and Venter (2016) found that the proportion of overall scheme benefits for South African projects is less but nevertheless significant. The Gautrain project proportion was 33% of benefits for time savings and the GFIP project was 38%. However these values were derived from VTTs whose provenance is unknown. Economic appraisals of the Rea Vaya Phase 1a and 1b routes (City of Johannesburg, 2012) found that the systems were marginally economically viable. However, the VTTs used in the analysis are not stated and can only be inferred. The provenance of the values used is thus uncertain.

4. FILLING THE GAPS IN OUR UNDERSTANDING OF WHAT IS IMPORTANT TO TRAVELLERS

Recent research into public transport mode choice and car route choice have highlighted utility attributes that are not taken into consideration in South Africa, but which have been shown to materially affect mode and route choice. These are discussed in Table 1. It is important to highlight that various household travel surveys (including the 2020 National Household Travel Survey (Statistics South Africa, 2020)) have highlighted attitudes and perceptions for modes of transport. While these are useful for assessment as attributes in the utility expression (e.g. comfort, congestion, crime and overcrowding) they are qualitative in nature and their relative importance has not, in most cases, been quantitatively estimated.

Table 1: New Insights into Factors of Trip Utility for Mode and Route Choice Simulation

Utility Attribute	Context	Discussion
Gender	Gautrain access and egress mode research.	Gender as part of the utility expression was found to be significant, especially for the walk and Gautrain bus access & egress modes. No quantitative assessment of gender as a significant attribute across all modes of public transport has been determined, especially those requiring extended walk and waiting components.
Personal safety	Gautrain access and egress mode research.	Personal safety was found to be very significant for those access / egress modes when there was a walk and/or wait component, i.e. the walk mode and the Gautrain bus mode. Correlation of this attribute with the gender attribute was assessed and found not to be significant, i.e. the attributes were individually significant in the modal utility expressions. The qualitative assessments from the NHTS (2020) highlight that crime and personal safety are a cross-model issue. Studies have highlighted the concerns that public transport users have in regard to their personal safety and their relative importance quantified in the utility expression (Watts, 2020; van Zyl et al., 2022).
E-Hailing Services	Gautrain access and egress mode research.	The growing importance of e-hailing modes for station access and egress trips was revealed in the sample of Gautrain users who participated in the SP study. E-hail modes can no longer be ignored as unimportant access/egress modes. This popularity is likely to increase with the introduction of mobility as a service (MaaS) platforms in South Africa.
Trip time reliability	Gautrain access and egress mode research.	The research by Watts (2020) highlighted the high disutility associated with modes with higher travel times and the uncertainty of that travel time, especially the Gautrain buses. The extended trip times of longer Gautrain bus routes and inability to adhere to time tables was associated with high levels of mode disutility.
Car commuter trip time reliability	Route choice simulation for Gauteng car commuters.	Trip time reliability was found to be significant when included in the route utility expression (Hayes, 2023). The willingness to pay for reliability could not be estimated due to the attribute levels used, i.e. reliability was measured as a probability of on-time arrival. This finding confirmed international evidence (Wardman & Ibanez, 2012) that trip time reliability can significantly contribute to route utility, in some cases to the same level as travel time savings.

Table 1: Cont'd

Utility Attribute	Context	Discussion
Free-flow, slowed-down and stop-start travel time	Route choice simulation for Gauteng car commuters.	Models estimated from route choice data (Hayes, 2023) showed that car travel at different levels of service on a route significantly affected route choice, with much higher levels of disutility associated with stop-start conditions. This finding should be used in the development of urban road policy, traffic management systems and the development of urban road networks and upgrade plans. The VTT's associated with these congestion levels should be used in the economic appraisal of road schemes and in transport demand models.
Urban tolling	Route choice simulation for Gauteng car commuters.	The route choice models by Hayes (2023) showed that car commuters in Gauteng were willing to pay tolls for travel time savings, with higher levels of payment correlated with increasing congestion levels. This result has important implications for the design of urban toll road systems, for example the ability to charge dynamic toll tariffs for counter-peak and off-peak travel conditions (i.e. in less congested conditions).
Toll road quality bonus (TRQB)	Route choice simulation for Gauteng car commuters.	Route choice modellers commonly allocate a toll road bonus to tolled routes to account for unobserved factors of utility such as perceived increases in route safety, lighting at night, emergency response times etc. This is commonly referred to as a toll road quality bonus (TQRB). However, the sample of car commuters used for route choice modelling in Gauteng by Hayes (2023) had a statistically significant but negative coefficient value for the TRQB. This meant that the sample had a negative perception for the unobserved factors of utility when using the Gauteng GFIP freeways. This result is not perhaps surprising given the negative public sentiment associated with the GFIP e-toll system. However, it confirms the findings for Australian urban toll roads, where the TRQB was also negative. The result underlines the risk associated with the conventional approach of simply assuming a positive toll road quality bonus when estimating the demand on urban toll roads.

5. CONCLUSIONS

Partly due to their complexity, but also due to an unappreciation of their importance, mode and route choice models in South Africa have not received adequate research and application attention. Due to the complexity of the model specification and the experimental designs required for both SP and RP surveys they are the most difficult sub-models in the four step modelling process to collect data for, to estimate and then apply in popular transportation software platforms. The net result has been the lack of budget allocation for data collection and limited effort into the development of more robust and relevant models. In many instances old models with uncertain provenance have been used introducing significant uncertainty and risk in modal demand and revenue forecasts. The net result has been over-estimation of modal demand and revenues when compared to the actual demand after implementation. While this error is not only because of poor mode and route choice modelling, the some cause can be put at the doorstep of inadequate choice modelling, including data collection and the choice of model used. The estimation of key microeconomic measures such as the willingness to pay for travel time savings cannot be done with any certainty without robust choice models. These microeconomic measures are key inputs into the economic appraisal process.

Currently in South Africa there is an inadequate understanding of mode and route utility attributes affecting mode and route choice. When identified and understood the important attributes can be planned for and incorporated into system designs, technical specifications and operating plans. The objective is to maximise user modal utility and thereby realistically maximise modal or route demand and associated revenues.

We need to upskill our ability to quantify urban traveller trip preferences and behaviour and incorporate these findings into policy and transport demand modelling. The first step in the upskilling process is for all stakeholders to appreciate the importance of the upskilling requirement. The pool of academics and practitioners skilled in the field of choice modelling in South Africa is alarmingly small. The risk of not upskilling is the repetition of past mistakes in regard to policy formulation, transportation systems and operations designs, inaccurate demand and revenue estimation, and the inadequate economic and financial appraisal of transport systems. The economic and financial consequences of erroneous demand and revenue estimation are enduring. Secondly, prioritising this research and the allocation of funding by all levels of government is necessary to fill the gaps we have in our current understanding of traveller trip preferences and the heterogeneity associated with VTT. As recommended by SANRAL (South African National Roads Agency Ltd, 2010), the medium-term objective should be the development of a standard set of national VTT guidelines for use in the economic appraisals of transport systems and in transportation demand models.

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